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Agenda Item: D.7.3

Canada

DEVELOPMENTS IN THE PRODUCTION, CASTING AND FABRICATION OF IRON AND STEEL IN RELATION TO SMALL TONNAGE STEEL PLANTS

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NOTES

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DEVELOPMENTS IN THE PRODUCTION, CASTING AND FABRICATION OF IRON AND STEEL IN RELATION TO SMALL TONNAGE STEEL PLANTS

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1. Introduction

(a) A close link between the economic development of a country and its steel consumption is well known[1]. Consequently, it is believed that the first efforts of less-industrialized countries should be aimed at developing iron and steel production for industrialization, an indispensable factor for social and hum progress.

(b) It is known that the majority of the under-industrialized countries are not able to obtain the steel tonnages which they require, but rather only the quantity which their capacity to import permits. One of the obstacles to the development of the steel industry in these countries is the general shortage of capital, which is of considerable consequence since development of a steel industry requires large investments. Capital is not the only scarce factor for industrially emerging regions. In many countries, the availability of foreign exchange to pay for imports represents a similar or even worse problem. It is, however, important to bear in mind that domestic production, even on a small scale, could well save a substantial percentage of the foreign exchange necessary to cover the delivered cost of imported steel.

2. Market-Size and Steel Works Capacity

(a) One of the most important factors in determining the capacity of a new steel industry is knowledge of the size of the market. It has been a common practice to estimate market demand on data, in most cases scanty, for the immediately preceding years. This method may lead to underestimation of the market in cases where unsatisfied demand existed because of limitations in the capacity to import. The main objective is to adjust the steel mill capacity to the dimensions of the market leaving room for future expansions. The capacity of a steel works has a prime influence upon production costs. In general, steel works with lower assembly costs (i.e., mining cost of raw materials plus haulage costs to the plant) and wage rates are in a more favourable position to face competition; that is, the minimum size will be smaller. The size of operation is also governed by other factors which influence costs. Among those of major importance may be mentioned the composition of raw materials, the distance of the plant from local markets, and so forth.

(b) Installation of an integrated steel plant based on classical production processes, including the reduction of iron ores by coke in blast furnaces, can be justified on economic grounds if the market demand of steel products is above a certain minimum.

Although the actual capital cost figures are difficult to give, it appears that blast furnace plants, including all auxiliaries, may cost from $60 to $90 per ton of pig iron annually[2], and a fully integrated steel works may cost in the order of $350 to $600 per ingot-ton of annual capacity, depending on the product mix, the capacity of the plant and its location.

(c) In addition to the excessive initial investment involved, a blast furnace unit lacks the flexibility of operation that must be reckoned as one of the requirements in less-industrialized countries where the market is small, say, less than 300,000 tpy. It appears that consideration should therefore be given to the many methods of iron ore reduction other than classical blast furnace since, in general, they need smaller investments, have greater flexibility of operation and employ a larger proportion of man power. In addition, they do not require good metallurgical coking coal. Among these methods, the following are the most important: electric iron smelting, low-shaft smelting, and numerous so-called direct reduction or direct iron methods, which produce in some instances a high grade product equivalent to scrap and in others some variety of pig iron with special characteristics.

(d) Figure I gives a general classification[3] of the various methods of making iron. It will be seen that there are a large number of direct reduction methods in various stages of development. There is no doubt that large coke-fired blast furnaces will continue to be the major producers of pig iron in areas where markets are large and metallurgical coke is available. The purpose of this paper is to examine briefly the scope of direct reduction and other non-conventional processes for the establishment of smaller steel plants in regions where the potential market is limited and the coking coals are not easily available. These small plants could meet a part of the regional demands and open the door to a variety of processing industries, which in turn would further accelerate the industrial development of the region.

(e) As stated earlier the direct iron processes are in different stages of development. Some are in commercial operation while others are in an advanced planning stage and are ready for immediate installation. Others are in the experimental stage, e.g., the SL direct reduction process[25] recently developed in Canada. Since a voluminous literature on these processes is available, only the few that have operated successfully as production processes will be described. There is no intention to imply superiority of one process over another. The choice, as stated earlier, will be made on the basis of the types and costs of fuel and energy available, capital costs/annual ton of capacity, market size, quality, quantity and type of ore, etc.

3. The Wiberg-Soderfors Process:

(a) The Wiberg method of manufacturing sponge iron has a long record of successful operation in several Swedish steel plants, the first industrial size unit being built in 1932.

(b) The ore must be in lump or pelletized form but the reducing atmosphere may be generated from coke or coal, or by cracking natural gas. Usually, the gas is produced from coke or coal in an elec-

trically heated carburetor. When coke is used as fuel, its sulphur content is largely gasified and occurs mainly as hydrogen sulphide in the gas. This sulphur is removed in a filter interposed between the carburetor and the furnace.

(c) According to one source[4] the estimated production cost in 1958, in a Swedish plant of 27,500 net tons annual capacity, was 280 Sw Cr per net ton of sponge iron (86% Fe), or about U.S. $53.70 per net ton. This is equivalent to about $62.46 per net ton iron in the sponge. The estimated cost was based on a total investment cost (excluding pelletizing plant) of $1.6 million.

4. HyL Process

(a) This direct iron ore reduction process has proven to be a commercial success. The process can be employed where scrap is either in short supply or expensive and where high grade ores (or concentrates) and cheap natural gas are available.

(b) The HyL process is a batch process in which rich lump ore is reduced in a retort by desulphurized hot reformed natural gas. This gas is passed through a fixed ore bed in the reactors for a period up to 4 hr. The ore, preheated to 850-1000°C (1500-1830°F), is 90% reduced to form sponge and is then stored hot or discharged directly to an electric melting furnace.

(c) Capital cost for a plant of the HyL type will vary according to local conditions. However, according to one estimate[5], HyL installations require about half of the capital investment required for a conventional blast furnace, including coke ovens, of the same capacity. The reported[6] capital investment for a 500 ton/day plant was estimated in 1958 at $30 per annual ton iron, and the operating cost was placed at about $10 per ton.

5. Krupp-Renn Process

(a) This process was developed over 25 years ago in Germany, and has probably enjoyed wider commercial application than any other direct reduction process. Basically, the Krupp-Renn process involves the continuous reduction of iron ore in a rotary kiln using coke breeze as a reducing agent and a pulverized fuel flame for heating. Gas or oil can also be used for heating. Reduction is not dependent on the use of lumpy metallurgical coke. A low-quality solid carbonaceous fuel can be employed to reduce a wider range of ores. This includes both low grade ores and ore fines. Furthermore, the process is amenable to siliceous ores. The mixture of gangue and metallic iron is discharged in a pasty condition and is known as "luppen" (nodules). Iron and slag are then separated by milling and magnetic separation. Sulphur pick-up from reducing material may present production problem.

(b) On the basis of published estimates[7,8], it appears that the investment cost of Krupp-Renn plant in 1958 was about $42 to $50 per annual ton of "luppen" containing 92-95%, and the cost of production was at DM200 ($45.75) per ton "luppen". In a more recent estimate Astier[9] gave a figure of 180 new French francs ($39.80) per ton of "luppen" made from siliceous ore of 30-33% Fe content.

I. Smelting	Shaft Furnaces	Conventional blast furnace; low shaft furnace (Demag-Humbolt)***
	Electric Furnaces	Tysland Hole*; Lubatti*; deSy Ghent***
	Electric Furnaces with Pre-reduction	Strategic-Udy***; Orcarb***; Dwight-Lloyd-McWane***
	Rotary kiln	Basset*
II. Flash Smelting		Flame Smelting (Cyclusteel)***; Jet Smelting***; Diamond Alkali
III. Direct Reduction gas reducant	Shaft Furnace	Wiberg-Soderfors; Lurgi Gafluser***
	Retort	Madaras***; Hyl*
	Fluid bed	Esso Little*; Nu-Iron***; Armco H-Iron***; Stelling***; Msgrigal
IV. Direct Reduction solid reducant		Tunnel kiln Hoganas-Sieurin*; Krupp-Renn; Bureau of Mines; R-N**; Bruckner*; Urquehart***

* Commercial. ** Semi Works. *** Pilot.

I. SMELTING

Class	Process Name	Principals	Description and Status
Shaft Furnaces	Conventional Blast Furnace		
	Demag-Humbolt		Low shaft furnace employs briquettes that include fuel, ore and limestone. Pilot plant 10-15 tpd has been run; new plant due with capacity of 100 tpd.
Electric Furnace	Tysland Hole	Elektro-kemisk	Conventional electric smelting; employs lump ore and electric arc; 100 furnaces in operation; 3-4 million tons capacity.
	Lubatti	Demag	Employs electric current through slag; commercial but not in wide use.
	deSy Ghent	U. of Ghent	Electric furnace with two components; pilot plant built.
Electric Furnace with pre-reduction	Elkem with pre-reduction kiln	Elektro-kemisk	Submerged arc furnace; pre-reduces and pre-heats ore in kiln.
	Strategic-Udy	Strategic-Koppers	Electric resistance and arc heating system; uses kiln for pre-reduction and pre-heating; 1000 kw semi-works plant in operation; letters of intent for two plants. One letter covers 300 tons day plant for Quebec South Shore Iron & Steel Co.
	Orcarb	Swindell-Dressler	Employs balls of fine ore and coking coal. This is heated, pre-reduced and passed through electric furnace. Pilot plant in Harmarville, Pa.
	Dwight-Lloyd-McWane	McDowell Co.	Pellets of fine coal and ore are passed into sintering machine; product goes to electric furnace.
Rotary Kiln	Basset	F. L. Smith Co.	Make liquid iron in kiln; commercial plants in Europe; an old process.

II. FLASH SMELTING

Process Name	Principals	Description and Status
Flame Smelting (Cyclosteel	British Iron & Steel Research Assn.	Pilot plant; makes iron, not steel.
Jet Smelting	Ontario Research	Natural gas and powdered ore mingled to produce iron; early pilot stage.
Diamond Alkali	Diamond Alkali Co.	Gas reactor for desulphurization of pig iron has been mentioned for possible application to iron making.

Others: Oster; Armco

III. DIRECT REDUCTION

(gas reductant solid product)

Class	Process Name	Principals	Description and Status
Shaft Furnace	Wiberg-Soderfors	Stora-Kopparberg	Coke or natural gas used as reducing agent; carbon fully oxidized to give high fuel efficiency.
	Shaft Furnace	Lurgi Gafluser	Pilot plant; no details.
Retort	Madaras	Madaras	Lump ore or pellets reduced by gas; pilot stage.
	Hyl, Hojalata y Lamina	M. W. Kellogg	Lump or agglomerated ore with reducing gas; 200 ton unit now operating; 500 ton plant coming.
Fluid bed	Esso Little	Esso Development Co., A. D. Little Co., Texas Co.	Pilot plant.
	Nu-Iron	U. S. Steel	Original 2 ton capacity pilot plant being refined.
	H-Iron	Hydrocarbon Research, Inc., Bethlehem Steel	Pilot plant built; second plant being built at Los Angeles with a capacity of 110 tons a day.
	Stelling	Stora-Kopparberg	Pilot plant.
	Others: Armco	Pilot plant.	

IV. DIRECT REDUCTION

(solid reducant solid product)

Process Name	Principals	Description and Status
Tunnel kiln	Hoganas Sieurin	Ore and coke heated in tunnel kiln; process long used in Sweden to produce high grade powdered iron. One plant in Riverton N. J.
Krupp-Renn	Fried Krupp Southwestern Engineering Co.	Kiln used to produce partially fused iron shot; applied to special ores. Thirty-five kilns have been built; many now inoperative.
Bureau of Mines	U. S. Bureau of Mines	Rotary kiln used to reduce coal, ore and limestone; semi-works plant was built. Project not active.
R-N	Republic Steel Corp., National Lead Co.	Kiln used to reduce ore and produce briquettes; can handle high phosphorous ores or high grade ores. Plant near Birmingham has capacity of 50 to 75 tons a day.
Bruckner	Kennecott Copper	Horizontal rotary kiln used to make sponge iron in connection with copper recovery; commercial.
Urquehart	Steel Processing Co. Fort Pitt Bridge Co.	Ore fines and carbon charged into inclined rotating tube; iron balls go after reduction; small test furnace.
Others: Freeman; Kalling Domnarfvet		

Figure I. General classification of the various methods of making iron[3].

6. R-N Process

(a) The Republic Steel-National Lead process employs a rotary kiln operating below fusion temperatures. Crushed and sized ore of a wide variety or balled fines are fed into the kiln along with the carbonaceous reducing agent. Limestone or dolomite is also fed to control the sulphur content of the ore and the reductant material. Coke breeze or char is used for reduction and for heating gas (methane) or oil. As the ore travels through the kiln, countercurrent to the flow of heat, it is dried, preheated and reduced. The discharged materials are separated by screening and by gravity and/or magnetic separation.

(b) Although more recent figures are not available, it may be interesting to point out that in 1958 the estimated capital cost of an R-N unit, with an annual capacity of 400,000 gross tons, was reported[10] at about $19.5 million, and the production cost was estimated at $43.20 per net ton of R-N briquettes containing approximately 80-90% metallic iron.

7. Submerged Arc Electric Smelter

(a) One of the most outstanding methods for reducing the requirement of metallurgical coking coal - at the same time making small scale ironmaking possible - is the electric smelting furnace[11]. Iron ore and carbon are reacted in an arc furnace to produce molten iron, slag and waste gas containing carbon monoxide and carbon dioxide in the ratio of about 5:1. Electric energy serves the purpose of heating while low grade carbonaceous material acts as a reducing agent. The electric furnace requires only one-half as much fuel/reductant per ton of iron as a blast furnace. However, electric smelting requires about 1850-2400 kWh of energy per ton of iron, and its commercial feasibility, therefore, depends on the availability of cheap power.

(b) In order to decrease power consumption considerable progress has been made in recent years in preheating and prereducing the burden in rotary or shaft kilns utilizing the by-product gas from the furnace, thus reducing the power requirement by almost 50%. In addition to some of the advantages outlined above, electric smelters operate efficiently in units with outputs as low as 100 tons per day.

(c) Estimated capital investment for an electric smelter (without preheating or prereduction auxiliaries) with a rated daily capacity of 800 tons of pig iron has been reported[4] at $60-$75 per annual ton.

8. Steelmaking and Remelting of Sponge Iron

(a) Steelmaking on a small or medium scale does not present the same problems as ironmaking. The basic oxygen or L-D converter process appears to be suitable for small scale conversion of pig iron to steel. Basically, the L-D process consists of blowing high purity oxygen (99-99.5%), vertically downward, through a water cooled lance, on the surface of molten iron in a closed bottom vessel lined with basic refractories. Scrap, iron ore or cold pig iron are added to regulate the heat. One of the advantages of the L-D process is the lower capital investment as compared with a conventional open-hearth

melting shop. In a recent study[12] in India it was shown that the capital cost of an L-D melt shop (including oxygen plant) was about 60% of the cost of an open-hearth plant of equivalent capacity, i.e., two-million ingot tonsper year. In terms of Canadian dollars the capital cost amounted to about $23.50 and $39.00 per ingot ton annually for L-D and open-hearth melt shops, respectively. These figures will be substantially higher for a smaller melt shop. It was also reported that the production cost of the L-D process was about Rs. 20 ($4.40) less per ingot ton than that of the open-hearth shop.

(b) A passing mention may also be made of the Savard-Lee bottom-blown converter process[13] developed recently in Canada. Instead of top lancing as in the L-D process, oxygen is injected at a high pressure into the bottom of the metal through a specially designed injector. It is claimed that the metal can be converted to steel without further refining in an arc furnace. The importance of electric arc furnaces for steelmaking, especially in countries with low cost electric power and adequate scrap supply, is known all over the world. Under favourable conditions of electric power and scrap supplies, electric furnaces produce steel at costs comparable with open-hearth furnaces. At the same time capital investment is appreciably lower, about 60% of the open-hearth. It must, however, be mentioned that in most of the under-industrialized regions the situation regarding power and scrap supplies is far from favourable. Till recently, one of the major drawbacks of electric furnaces for the production of plain carbon steels was that they are not effectively adapted to molten iron charges. However, recent studies have shown the feasibility of refining molten pig iron in the electric arc furnace, thus improving its economics and increasing its scope.

(c) This brings up the question of using direct reduced iron or sponge iron as a substitute for cold scrap. In fact, extensive work on the utilization of sponge iron for steelmaking has been carried out in the last ten years and very promising results have been reported. It is no secret that Sweden uses a greater tonnage of sponge iron per year than possibly any other country at the present time. Similarly, HyL sponge[5] has been in use for electric steelmaking in Mexico since 1958. Weaver[14], Farley[15], and Babcock[16] investigated the melting of R-N briquettes in electric furnaces and more recently Masi and Cannizzo[17] reported that direct reduced iron is a good component for the cold charge of electric furnaces and that it can be tolerated in open-hearth melting.

(d) Although considerable progress has been achieved in the technique of remelting sponge iron in electric furnaces, there are still a number of problems. For instance, it is generally known that the power consumption may be increased by 10-25% when sponge is substituted for steel scrap. In addition, the fluxing of a large percentage of gangue results in a very large slag volume in the electric arc furnace. According to Armstrong[4] the concentration and briquetting of the metallic fraction of the sponge would eliminate or reduce many of these problems but would add to both capital and operating costs.

(e) In addition to the use of direct reduced iron in electric steelmaking, investigations have also been carried out to utilize it as a melting stock in basic hot-blast cupolas. In a recent study[18]

in Germany it was shown that direct iron briquettes containing 88-91% metallic iron and 0.3-0.4% carbon can be successfully remelted in a hot-blast cupola with a capacity of 20 tons per hr. The liquid metal produced was suitable for open-hearth and L-D practice, and analysed 3.80-4.20% carbon and 0.02-0.04% sulphur. The conversion costs (excluding the cost of briquettes) compared favourably with 100% steel scrap melting, and approximated the attractive figure of DM 40.00 (U.S. $10.00) per metric ton of the liquid metal produced. It was, however, reported that coke consumption for the remelting of briquettes was slightly higher than the all scrap melting.

9. Basic Hot-Blast Cupola

(a) Suggestions have been made to integrate some of the direct reduction processes into foundries with a view to reducing their cost of iron and their dependence on outside source of pig iron and scrap. It appears that hot-blast cupolas for steel plants and for foundries have acquired enormous interest in recent years. It has been said that basic hot-blast cupolas may be one means of providing hot metal for steelmaking without the construction of additional blast furnaces, particularly for smaller plants when the relatively small investment cost for added capacity is considered.

(b) According to Harman[19] the combination of basic hot-blast cupola and oxygen converter or L-D plant ranks among the lowest in capital cost and production cost for ingot producing facilities. On the basis of published information the capital cost of a hot-blast cupola plant is placed at about $7 to $10 per ton of annual capacity, and the net cost of production is estimated in the order of $40 to $50 per net ton of liquid metal, depending on the cost of metallic and fuel charges.

(c) The cold-blast acid-lined cupola is still the most widely used melting furnace for cast iron and it seems that this situation will remain for many years yet, although the economic advantages of using heated blast will cause an increase in the number of such installations. One of the most widely used methods of regulating the carbon content of grey iron melted in a cold-blast cupola is to adjust the pig iron in the charge. Since this material is the most expensive component of the charge, newer techniques have been suggested[20] of controlling the final carbon content, particularly at the higher levels. The most successful answer to this problem is the carbon injection process. Briefly, the process consists of injecting fine particles of graphite or other carbonaceous material by a stream of relatively inert gas, such as nitrogen, through a graphite lance immersed in the liquid metal. Generally, the carbon pick-up depends on the feed rate and carbon recovery. Therefore, the major operating factor that affects carbon pick-up is the immersion depth, which acts on both components. One of the factors that tends to limit the application of the process is the increase in sulphur content as the pig iron charge is decreased. However, it has been suggested that simultaneous desulphurization and carbon injection may offer a solution to the problem.

(d) On the basis of long term tests in Canada it was estimated[20] that a saving of about $6.15 per net ton of metal charged can be realized.

10. Continuous Casting

(a) As a result of the great technical progress that has been made in recent years, it is now considered practicable to replace the orthodox stages of ingot mould casting, stripping, soaking pits, and primary rolling in small steel plants by the adoption of continuous casting[21]. By eliminating these production stages the investment cost of a steel plant can be appreciably reduced. There are a number of machines in various parts of the world that cast billets, blooms and slabs in continuous lengths on a commercial scale and several more are in the experimental stage or under construction.

(b) Advantages of the continuous casting process become apparent in making comparisons with conventional casting. The yield of metal is greatly increased. For instance, improvement of 10 to 12% in the overall yield of the primary rolled product from liquid metal has been reported[22]. Characteristic high surface quality of the continuous cast product has practically eliminated the need for surface conditioning. The other main advantage of the process is that the low capital investment makes it quite practical to locate plants to suit the market and to take advantage of favourable freight rates. These are some of the features that will be particularly attractive to less-industrialized regions where the production rates contemplated are not very high.

(c) The economics of investment and operating costs are difficult to give. However, the figures published[23] in 1957 indicate investment cost of approximately $17 per ton and about $7 per ton for machines having an annual capacity of 50,000 tons and 300,000 tons, respectively. These costs and the corresponding amortization are believed to be considerably lower than those prevailing in integrated steel works based on cogging and other primary mills. The cost increment would be in the order of 50-70% or more for a conventional plant, depending upon the location.

(d) According to one source[24] the net saving per ton of low carbon steel billets produced by continuous casting is estimated at about $8 - $10. This is equivalent to reducing billet costs by about 12%. On the basis of published information it appears that in works with outputs ranging from 50,000 tons to 300,000 tons per annum, continuous casting may replace conventional ingot casting, soaking pit and primary mill practice with an appreciable saving in investment and operational costs.

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SUMMARY

1. The developments in the production of steel, under circumstances where market demand is not sufficient to maintain a modern blast furnace integrated with a steel mill, are discussed briefly.

2. One of the obstacles to the development of an integrated steel industry in under-developed countries is the general shortage of capital, which is of considerable consequence since a steel industry requires large investments.

3. Installation of an integrated steel plant based on classical production processes, including the reduction of iron ores by coke in blast furnaces, can only be justified on economic grounds if the market demand of steel products is above a certain minimum.

4. In addition to the excessive initial investment involved, a blast furnace unit lacks the flexibility of operation that must be reckoned as one of the requirements in less-developed areas where the market is small. It appears that consideration should therefore be given to the many direct reduction methods of making iron other than conventional blast furnace since, in general, they need smaller investments, have greater flexibility of operation, use low-grade fuel and employ a large proportion of man power.

5. There are a large number of so-called direct reduction processes in various stages of development, which produce, in some instances, a high grade product equivalent to scrap and, in others, some variety of pig iron. The choice of the process will depend on the types and costs of fuel and energy available, capital costs/annual ton capacity, market size, quality, quantity and type of ore, etc.

6. Steelmaking on a small or medium scale does not present the same problems as ironmaking. The basic oxygen or L-D process appears to be suitable for small scale conversion of pig iron to steel. One of the advantages of the L-D process is the

lower capital investment as compared with conventional open-hearth melting shop.

7. Under favourable conditions of electric power and scrap supplies, electric furnaces produce steel at costs comparable with open-hearth furnaces. At the same time, capital investment is appreciably lower, about 60% of the open-hearth. It must, however, be mentioned that in most of the less-industrialized regions the situation regarding power and scrap supplies is far from favourable.

8. The use of direct reduced iron as a substitute for scrap in steelmaking has been studied extensively in recent years. Although investigators have reported promising results on the utilization of sponge iron as melting stock for electric furnaces, open-hearths, basic oxygen converters and hot-blast cupolas, there are still a number of problems. Suggestions have been made that concentration and briquetting of the metallic fraction of the sponge would eliminate or reduce many of the problems but would add to both capital and operating costs.

9. A brief mention is made of hot-blast cupolas for steel plants and foundries. It appears that basic hot-blast cupolas may be one means of providing hot metal for steelmaking without the construction of additional blast furnaces, particularly for smaller plants. The combination of hot-blast cupola and oxygen converter plant seems to rank among the lowest in capital cost and production cost for ingot producing facilities.

10. Attention is drawn to the use of carbon injection technique to raise the carbon level of grey cast iron melted in a cold-blast cupola. It seems that a substantial saving in the cost of metal charged can be realized by this technique.

11. Application of the method of continuous casting is mentioned briefly. It is pointed out that in works with outputs ranging from 50,000 tons to 300,000 tons per annum, continuous casting may replace conventional ingot casting, stripping, soaking pit and primary mill practice, with an appreciable saving in investment and operational costs.

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Agenda Item: D.7.3

Finland

AUTOGENOUS GRINDING - A KEY TO ECONOMIC PROCESSING OF MINERALS

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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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Autogenous grinding - A key to economic processing of minerals

by

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Most processing of mineral raw materials includes grinding as one of the basic steps. Grinding, however, is always an expensive process. Its expense results from two major sources: the cost of the metallic grinding medium and the cost of power. Of these the cost of the metallic medium, generally rods and balls, may exceed even one half of the total cost of grinding.

In the metal mining industry, grinding is conventionally performed in one of the following two ways: 1. Crushed ore is reduced in a single stage grinding circuit consisting of a ball mill in closed circuit with a mechanical classifier. 2. Crushed ore is reduced in a two-stage grinding circuit consisting of a rod mill in open circuit followed by a ball mill in closed circuit with a classifier or a cyclone.

Autogenous grinding can be defined as a grinding process where the grinding medium and the material to be ground consist essentially of the same solid material. Autogenous grinding has been applied in practice for over half a centary, notably in the gold mining industry in South Africa [1]. The conception that other ores also, in fact most ores can be ground autogenously is slowly gaining general acceptance. Actually the economic possibilities of autogenous grinding process - by the complete elimination of the gradually increasing cost of the metallic grinding medium - are truly attractive.

(1. Jackson, O.A.E., Pebble Milling Practice at the South African Gold Mines of Union Corp. Ltd, Trans A.I.M.E., 214, 1133-1144 (1959)

Many early attempts to apply autogenous grinding in practice have resulted in failure. This is beaause too much has been expected of autogenous mills. A mill equipped with an autogenous medium can never have the same grinding capacity as the same mill equipped with a steel medium, under the otherwise same operating conditions.

Two principle fields exist in the application of autogenous grinding. The first field includes conversions of existing grinding operations from metallic medium to autogenous. The second field includes new grinding plants which from the very beginning are planned to be autogenous. This paper deals primarily with the first field.

Before the conversion of an existing grinding operation from metallic medium to autogenous can take place, the following basic points must be thoroughly analysed:

(a) The number of autogenous mills required to treat the tonnage to be ground in units of the size originally applied with metallic medium.

(b) The size of the autogenous grinding units each of which would have the same capacity as each of the original mills with metallic medium.

(c) The possibility to separate, store and feed autogenous medium.

As indicated by points (a) and (b), a conversion may be achieved by installing a number of new mills, or by retaining the original units by enlarging e.g. the diameter of these mills. The latter method described in detail by Crocker [2] is far more economical. It has the decided advantage that the conversion may be limited only to a new enlarged mill shell and a new pinion. The original mill heads with bearings, spur gear and drive with motor may be retained as such.

To get a clear conception of what an autogenous mill can do, a useful study can be made on the so-called base mill power index.

(2. Crocker,B.S., Screened Ore Used for Fine Grinding at Lake Shore Mines, Trans. A.I.M.E., 193, 499-508 (1952)

The base mill has been defined by the author [3] as a cylindrical mill, 1 meter in effective inside diameter, and 1 meter in effective inside length. The base mill power P_1 is the net power in kW that a base mill will draw. The index corresponding to any grinding operation can be obtained by solving the following equation

$$P_i = \frac{P_n}{D^{2.5} L} \quad kW \qquad (1)$$

where P_n is the net power in kW drawn by the mill in question, D its effective inside diameter and L its effective inside length, both in meters. Because the net power drawn by the mill is not generally available, the total power index and total power draft (including tumbling power plus idling power of an empty mill) can be used instead as fair approximations. In general, the idling power amounts to about 10 % of the total power drawn by a mill operated with steel medium.

By the application of the base mill power index simple comparisons become now possible between mills of different sizes, grinding with any type of medium of any specific gravity, and at any speed.

Fig. I gives a series of fundamental base mill curves for wet grinding in grate and peripheral discharge mills. These curves show the maximum power in function of mill speed that can be introduced into a base mill Ø 1 m x 1 m equipped with media whose specific gravity is given on the curves. As an example it can be seen that at a convetional subcritical speed of 80 % of the theoretical critical about 12 kW of (net) power can be drawn by a base mill equipped with steel rods and balls, about 7.5 kW with autogenous medium having a specific gravity of 4.0 and about 4.5 kW with autogenous medium having a specific gravity of 2.7. It is generally accepted that the grinding capacity of a mill is directly proportional to the (net) power draft of the mill. The relative capacities of the base mill under the three conditions cited are 100, 51 and 34 units, resp.

(3. Hukki, R.T., Fundamental Study of the Grinding Characteristics of Tumbling Mills. Proceeding of the International Mineral Processing Congress, the Institution of Mining and Metallurgy, London, 7-23 (1960)

The following examples should be illustrative of cases where a conversion of a grinding operation from metallic medium to autogenous has been affected:

(i). In a concentrator in Finland [4], an overflow mill Ø 2.5 m x 3.6 m was operated at a speed 74 % of the critical with a ball load occupying 35 % of its inside volume. Under these conditions the mill drew 290 kW. The calculated base mill total power index becomes 8.2 kW. The relatively low value of the index is indicative of two negative features, viz. of the overflow type mill and of the lower than optium ball charge.

(ii). The ball load in the mill cited above was replaced by an autogenous medium load (specific gravity 3.6) occupying 55 % of the inside mill volume. Furthermore, the pulp density was lowered so that the percent solids figure in the mill discharge pulp dropped from 60 % to 45 %.

It is generally accepted that the power draft and the grinding capacity of a mill are directly proportional to the effective specific gravity of the medium, other condtions remaining unchanged. By the effective specific gravity is meant the difference between the true specific gravity of the medium and the boyant effect of the pulp surrounding the medium piece in the mill.

By assuming that the boyant effect of the pulp inside this overflow type mill would correspond to the values given above (60 % solids = sp.gr. 1.76; 45 % solids = sp.gr. 1.48), the effective specific gravities of the two media would be:

Balls	7.8 - 1.76 = 6.04
Autogenous medium	3.6 - 1.48 = 2.12

The corresponding new power draft after the conversion should be

$$\frac{(55/100) \times 2.12}{(35/100) \times 6.04} \times 290 \text{ kW} = 160 \text{ kW}$$

The measured power draft after the change was actually 150 kW. The respective calculated base mill total power index was now 4.2 kW.

(4. Tanner, H. - Heikkinen, T.; Crushing and Grinding at Outokumpu. Progress in Mineral Dressing. Transactions of the International Mineral Dressing Congress, Stockholm, 123-138 (1957)

(iii). The same mill was changed from an overflow type mill to a grate type mill by installing an inside grate of the Marcy type. By assuming that the boyant effect of the pulp within the grate mill = 0, the maximum value for the base mill total power index could be based on the previous figure of 4.2 kW as follows:

$$\frac{3.6}{2.04} \times 4.2 \text{ kW} = 7.4 \text{ kW}$$

The measured total power draft after this change was 239 kW. The respective base mill total power index based on the original mill dimensions is 6.7 kW, or about 10 % less than the figure obtained above. It should be taken into account that due to the installation of the grate, the effective mill length was reduced by about 5 %. Furthermore, it should be natural that the boyant effect of the pulp even inside a grate mill cannot be = 0. Therefore it is only reasonable that the measured index is less than 7.4 kW.

(iv).From Fig. I it can be seen that, for a medium 3.6 in specific gravity, about 6 kW net power can be introduced into a base mill at a speed 74 % of the critical. By adding 10 % to this for a compensation of the idling power, the respective total power index based on the fundamental base mill curves checks well the measured value of 6.7 kW reported in experiment (iii).

(v).The overall end result based on the indicated conversions, first from steel medium to autogenous medium, followed by a change from overflow to grate type mill, is shown by a reduction in total power draft from 290 kW to 239 kW. Accordingly, the respective reduction in capacity should be about 17.5 % only. Part of this can still be recovered in the form of medium wear reporting in the final product. Its share was found to be about 5 % of the total tonnage ground in this case.

(vi).From Fig. I it can further be seen that the net power draft and correspondingly the capacity of a grinding unit can be increased by increasing the mill speed. The original capacity of this particular grinding operation could obviously be recovered at a speed near 100 % of the critical.

(vii).At Lake Shore in Canada [5] a group of Ø 5′x 16′overflow

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(5. Crocker, B.C.

ball mills were changed to grate type autogenous mills grinding with ore pebbles 2.66 in specific gravity. At the same time the diameter of each mill was enlarged so that the power consumption and the capacity of each unit remained unchanged.
With the steel medium the power draft was 182 hp or 135.5 kW at a speed 83 % of the critical. The respective total power index was 10.2 kW.
From Fig. II it can be seen that about 4.65 kW net power can be introduced into a grate type base mill with autogenous medium of 2.66 in specific gravity (point A in Fig. I). With idling power included the total power index would be about 5 kW. The total number of autogenous base mills needed for an equivalent grinding operation would be in these two cases

$$\frac{135.5 \text{ kW}}{4.65 \text{ kW}} = 28.3 \qquad \frac{135.5 \text{ kW}}{5 \text{ kW}} = 27.1$$

If the length of the autogenous mill is assumed to remain at 4.8 m (= 16 ft), the corresponding diameter x would be

$$x^{2.5} \cdot 4.8 = 28.3 \qquad x^{2.5} \cdot 4.8 = 27.1$$
$$x = 2.04 \text{ m} \qquad x = 2.00 \text{ m}$$
$$x = 6'8" \qquad x = 6'7"$$

At Lake Shore the new diameter of the autogenous mills was found to correspond to 6'8" after extensive and time consuming experiments in the laboratory and in plant scale.
It is seen again that the fundamental base mill curves give a satisfactory basis for the evaluation of mill sizes in autogenous grinding.
(viii).It can further be seen from Fig. I that autogenous grinding offers very interesting possibilities within the supercritical speed range, in practice at speeds between 100 % and 150 % of the critical. Preliminary experiments conducted in pilot plant scale have indicated that wet autogenous grinding is fully possible within the said range, even under conditions such that the mill automatically forms its own semiautogenous lining of the chage within the mill (6. The grinding medium, material to be

(6. Hukki, R.T; An Analysis of the Potentialities of Autogenous Grinding Mills, Paper, presented at the 1st European Symposium on Size Reduction in Frankfurt (Main), Germany (1962)

ground, and even the mill lining consists now of the material to be ground. These experiments are being extensively continued in pilot plant scale.

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Autogenous grinding has been applied in South African gold fields in primary, secondary and tertiary steps of grinding (7. It is therefore reasonable to expect that the autogenous coarse grinding mill can replace the conventional rod mill just as autogenous fine grinding mills have already replaced fine grinding ball mills in many plants. Such a two stage autogenous grinding system has recently been successfully tested on a large scale in Finland (8. The standard sizes of rod mills are Ø 6′x 12′and Ø 9′x 12′. Before autogenous grinding of conventional relatively coarse rod mill feed can be successfully performed, the respective primary mill should have a large diameter, at least 9′, preferably larger, and the autogenous medium should be sufficiently coarse. The fundamental base mill curves given in Fig. I can again be used for mill size evaluation.

In all autogenous grinding, large tonnages of autogenous medium are needed. In the South African gold fields, the various types of media are picked by hand(9. The technical solution is the separation of suitable size fractions by screening from the crushing circuit (10. It should be natural that medium pieces used for coarse primary grinding should be more massive than those used for fine secondary grinding. The best size range may vary from case to case. The primary medium may consist of pieces lo - 25 cm in size, the secondary medium 25 - 75 mm in size.

Crushing plants do exist where it would be difficult, if not impossible, to separate autogenous media by screening. Such a difficulty may, in an extreme case, prevent an economical conversion of the grinding plant to autogenous.

(7. Jackson, O.A.E.

(8. Heikkinen, T. - Lehtonen, E.; Uber Versuche mit zweistufiger autogener Mahlung in Outokumpu, Erzmetal 402-407, (August 1962)

(9. Jackson, O.A.E.

(10. Crocker, B.S.

Storage of the separated medium should take place in silos of suitable size. Feeding of the medium from a silo to grinding units may be continuous or intermittent.

At Lake Shore [11], the conversion of a Ø 5′x 16′mill to a Ø 6′8" x 16′mill was achieved at a cost of $ 5050 per mill (1952). To this must be added expenses in separation, storage and feeding of the media. In a normal case, energy consumption should remain unchanged. On the credit side are the great savings in the cost of grinding medium. All metallic medium, rods and balls, can be eliminated. Just how great the potential savings will be in a given case can be easily evaluated by any mill superintendent who well knows what he is paying for his metallic medium. He should not be surprised if, in an extreme case, the yearly saving may equal the entire cost of his mill.

(11. Crocker, B.S.

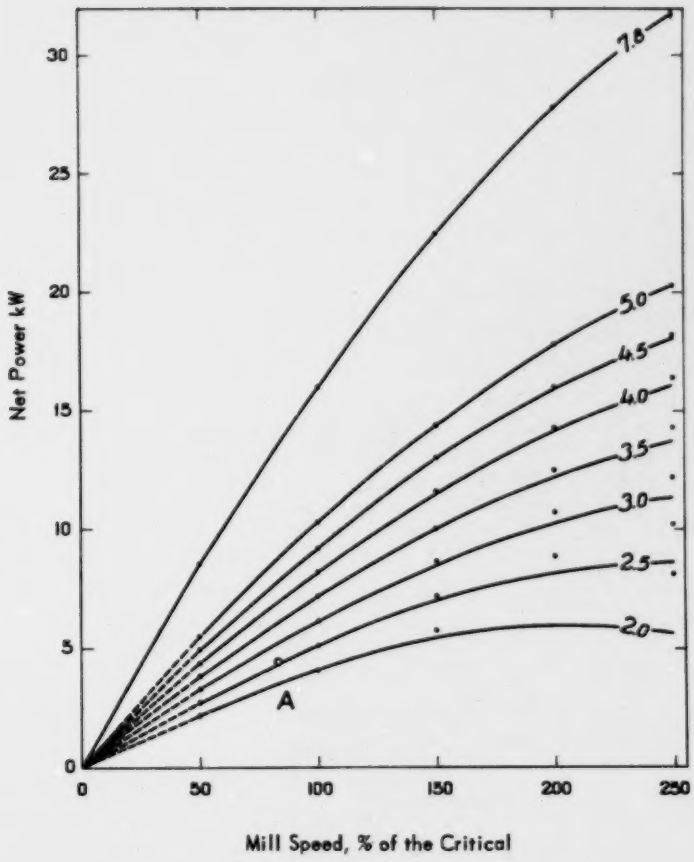

Fig. I - Fundamental base mill curves for wet grinding in grate and peripheral discharge mills

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FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

SUMMARY

Agenda Item: D.7. Finland

AUTOGENOUS GRINDING : A KEY TO ECONOMIC PROCESSING OF MINERALS

By R.T. HUKKI, Professor,
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Finland

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Autogenous grinding - A key to economic processing of minerals

by

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Summary

(a) Due to the increasing high cost of metallic grinding media such as rods and balls, the use of autogenous medium should be seriously considered.

(b) Autogenous grinding is well applicable in most industrial grinding operations.

(c) Conventional coarse grinding with rods can be replaced by autogenous primary grinding.

(d) Conventional fine grinding with balls can be replaced by autogenous secondary grinding.

(e) Existing grinding plants can be converted from grinding with metallic medium to autogenous at a relatively low cost.

(f) No new grinding plant should be built without a consideration of autogenous grinding.

(g) Autogenous medium needed for primary grinding is coarser than that used for secondary grinding.

(h) Autogenous media are separeted by screening from the crushing circuit.

(j) The capacity of an autogenous grinding mill is always less than that of the same mill with metallic medium, both operated under otherwise the same conditions.

(k) Fig. I gives a series of fundamental base mill curves which can be used in the evaluation of mill sizes for any wet autogenous grinding operation.

(l) A number of numeral examples are given to demonstrate the applicability of these curves.

(m) Autogenous mills can be operated at subcritical as well as at supercritical speeds.

(n) Interesting possibilities exist for running autogenous mills at supercritical speeds in such a way that the material to be ground, the grinding medium and even the automatically renewable semiautogenous lining of the mill all consist of the material which is the subject of the grinding operation. These new possibilities are now being extensively studied.

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Agenda Item: D

Hungary

INDUSTRIALIZATION IN ECONOMICALLY LESS DEVELOPED COUNTRIES

By Dr. János SZITA,
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INDUSTRIALIZATION IN ECONOMICALLY LESS DEVELOPED COUNTRIES

by
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1. The economically less developed countries are generally considered to be on an earlier stage of economic development than the industrialised countries of to-day. But that is not quite true. The situation of the developing countries now essentially differs from the situation in which the highly industrialised countries of our time were a couple of centuries ago. An overwhelming part of the underdeveloped countries were entirely dependent in the political as well as economic sense of the word and many of them were even some years ago under colonial rule. Distorted economy, a very low level of economic activity and standard of life is the inheritance of the recent past.

2. In examining the way of future development of the developing countries one may see a multiple dependence of these countries. They are entirely dependent in respect of foreign trade. Most of these countries have a monocultural economy, their export consists of a few commodities, mainly of raw materials and foodstuffs. On the basis of the experiences of the last decades one may say that the export goods of the developing countries make up the least dynamical sector of the world's trade. This situation will hardly change in the future, since one of the characteristics of the technical revolution of our age is the fact that industry, as compared to the value produced, needs less raw material, and consequently the demand for raw materials relatively or - in the case of some products - absolutely diminishes. The participation of the economically less developed countries in the world's export exclusive of the socialist countries diminished from 28.3 % in 1953 to 24.1 % in 1960. If we consider that in most of the developing countries half of the national income, or sometimes three - fourths, is realised through foreign trade, we may see one of the major difficulties of the economic development of these countries. And if we realise that the developing countries meet their economic requirements almost exclusively by way of import - even many agricultural countries import most foodstuffs for the provision of the population - their economic situation and dependence in this respect appeares more than critical. The prevention of a further deterioriation of the situation and the assuring of the future development require the liquidation of the monocultural structure, the diversification of the economy on the line of industrialisation.

3. Dependence has come about also in the domain of technics. The developing countries are dependent in regard to the procurement of capital goods necessary for economic development. In consequence of the adoption of the system of technical standards most of the developing countries are dependent on the machine and spare part supplies of the former mother countries. Orientation to new markets of supply is therefore greatly rendered difficult by the standard system applied in many former colonies. This aspect of dependence too can only be liquidated through extensive industrialisation. Economic dependence appears also in many other respects, as for example: foreign exchange, provision with manufactured goods, transport, specialists, and last but not least in the fact that developing countries do not dispose freely of considerable part of their natural resources controlled by foreign interests.

4. It is widely discussed wich methods are suitable for the economic development of less developed countries. Not long ago many representatives coming from certain highly developed countries objected to industrialisation of the less developed countries, guided by the desire to preserve the present international division of labour. However, this viewpoint has become untenable in our days and industrialisation has been generally accepted as the only effective way for the development of less developed countries. At present it is generally recognized that it is industrialisation which renders possible the speedy increase of the national income and creates new possibilities for economic development. Industrialisation increases the rate of employment, creates new job opportunities and, as a result, promotes the growth of the purchasing power, the extension of the inner market. Last but not least, industrialisation when creating a differentiated economy helps liquidate the economic and political dependence of the developing countries.

5. All this should not be interpreted in a way as industrialisation ought to be considered as the only and exclusive remedy of underdevelopment. Beside industry other branches of the economy - agriculture, fishing, etc. - ought to be developed too. But this must be in organic interdependence with industrialisation. For instance, the intensive development of agriculture is hardly conceivable without a growing production of building materials, of some branches of mechanical engineering, of the chemical industry, and so on. And conversely: industrialisation is in many respects conditional on a differentiated development of the commodity production of agriculture, the growth of the purchasing power of the peasantry, etc. The economic life of a country should be viewed in its complexity, in its interconnections, industrialisation being considered as the main lever.

6. The absolute necessity of industrialisation itself does not determine which branch or branches of industry should practically be developed. It would be quite wrong to recommend for every country to develop equally all branches of industry. Such tendency of autarchy would leave out of consideration the advantages of international division of labour, would disperse the economic resources of the country, would renounce utilising the specifically favourable conditions of the different countries and would certainly not lead to a fast uprising of the economy. The local and specific situation, the international connections as well as all the

possibilities and conditions for industrialisation ought to be carefully considered individually in every country. As first task it should be established which factors might primarily influence the trend to be set for industrialisation. Some factors should be here mentioned.

a. Natural resources.

Generally it is practicable to develop those industries for which the raw materials can be found in the country or are relatively easy to procure in the framework of regional cooperation. For instance, the development of steel industry is suitable where coal and rich iron ore, or at least one of the two, are on the site. The same holds good in respect of non-ferrous metallurgy and - partly - of the chemical industry where, however, other factors too - such as electric energy - come into play. The existence of the sources of energy is also a decisive factor. Generally one or several of the different sources of energy - coal, oil, natural gas, hydraulic energy - are available in every country. For industrialisation it is absolutely necessary that the production of energy be in excess over the energy requirements of industry in the long run, too. This must be taken into consideration already in the first phase of industrialisation. Generally where raw material exists it is practical - beside the mining of raw materials - to organise the processing industry, such as metallurgy, founding, etc. This is reasonable because a less developed country may obtain more favourable prices with semi-finished and finished products than with raw materials. For instance: the price of one ton of bauxite on the world market is $ 6 to 7, while the price of one ton of aluminium is $ 430 to 500, i.e. 70 times as much. Oil, an important material of modern industry and communication, may be mentioned as well, though the prices of oil are not established exclusively by a free market. The difference between the prices of crude oil and finished products is immense. For this reason the effort of some less developed countries which are oil producers to develop oil-distilleries of their own is quite reasonable.

The increase of the rate of processing is also motivated by the fact that while the prices of ores and primary materials fall, the prices of finished products rise or are stationary. In any case the price trend of finished products does not deteriorate the terms of trade of a less developed country so much as does the price trend of raw materials. That may be illustrated by the following table:

Price trend in foreign trade

	1948	1960
Prices of primary products	100	91
Prices of manufactured products	100	116
The purchasing power of raw materials in manufactured goods	100	78

Source: World Economic Survey, 1956 and Monthly Bulletin of Statistics, 1961.

Of course, the development of processing, or manufacturing industry must be preceded by careful market-research if the greater part of the products goes to export.

Besides it must be stated that the stock-taking of the natural resources of a country and the fixing of the trend of development demands that the developing country should freely dispose of its natural resources. This is an inalienable right of every country. It is contrary to this basic principle that certain forces cling to the prerogatives acquired in the period of the colonial system. This situation ought to be liquidated, and every country should freely dispose of its natural resources. This is one of the fundamental requirements for the realisation of industrialisation.

b. The level of development of production is also an important factor in determining the line of industrialisation.

It must be taken into consideration which branches of industry exist in a country, whether or not their further development is reasonable, or with what and to which extent these branches can promote industrialisation, what accumulation they can ensure etc. The situation of agriculture, too, is essential from the point of view of commodity production, surplus labour, the demand for manufactured goods in the period of development, etc. It may happen that the industries processing the raw materials into semifinished or finished products should have priority in the first phase of industrialisation of various countries. However, it must be taken into consideration that in the case of many developing countries it might be not reasonable to satisfy the machinery requirements of the new branches of industry entirely from abroad. Therefore it might be advisable to develop some branches of engineering in the countries concerned. The same applies to certain branches of industry producing consumer goods, considering the rapid increase of demand for these goods even in an early period of industrialisation. The state of the network of communication, too, is a decisive factor. Though investments in the field of communication are very slowly reimbursed, they are indispensable for industrialisation, too. The trend and development of the network of communication can influence the settlement of the newly established industry. Infrastructure ought to be considered equally as many of its elements may determine the possibilities building up new industries.

c. The composition and level of domestic consumption.

A common experience of industrialisation is that the purchasing power and domestic consumption increase rapidly in consequence of a greater rate of employment. To ensure the former level of consumption and then to cope with the rapidly increasing new requirements in this respect cause mostly a considerable increase of imports. It seems reasonable to develop some branches of the light industry, the food industry, to ensure a many-sided commodity production of agriculture, in order to meet the needs in foodstuffs and other consumer goods from domestic sources.

d. The situation of labour.

Industrialisation requires more hands and many skilled workers. Therefore the labour situation in a country should be appraised not only as to the possibilities of securing the necessary labour force but also as to how many skilled workers, technicians, engineers

and economists are at disposal. The last categories are essential for the training of skilled and semiskilled workers. In perspective the aim should be full employment for the population. This is a task not for a few years. The assuring of the accommodation, provision and sanitary care of workers on the site of the industrial settlement should also be borne in mind.

e. Level and structure of foreign trade.

At an early stage of industrialisation there is a sudden increase in the import of goods for consumption as well as for investments. This raises immediately, of course, the problem of the balance of trade and payments. At the same time the radical and quick shift in the former structure of foreign trade causes serious troubles. For this reason it is important to practise stricter economy in imports, possibly to introduce the planning of foreign trade, or in any case, the control of imports. This requires, as a rule, the creation of a central organ which takes stock of the import needs and issues import permits on this basis. This is the only way of giving priority to goods necessary for industrialization and setting reasonable limits to the importation of less important goods. At the same time - according to established principles of economic development - steps must be taken towards gradual transformation of the structure of export in keeping with the possibilities of the country and the needs of the world market. This is, of course, connected with the differentiation and extension of the markets which, in the last analysis, helps lessen the one-sided economic dependence of the developing country.

7. The factors mentioned above prove unequivocally that the industrialisation of less developed countries is a complex task requiring immense financial means, an important staff of experts and efficient organisation. It is a novel task which calls for a radical transformation of the international division of labour. Especially the present relationship existing between western countries with highly developed industries, on the one hand, and economically less developed countries, on the other hand, should be altered. A considerable part of the industry of the former is based upon the raw materials and natural resources of the latter. Of course, in this problem immense interests are at stake. But today it is clear that the industrialisation of the developing countries is to the interest of the whole world, and the less developed countries ought to play a quite different role in world economy. Their independence must be assured in the economic sense too and this is of primary importance. Today it is not enough to acknowledge the importance of industrialisation in principle, practical deeds are necessary. And as the development of the economically less developed countries is a task to be undertaken in the interest of the whole world, a world-wide concerted action is necessary. For this aim not only a radical transformation of the division of labour between developed and less developed countries is needed, but also cooperation among all highly developed countries in this respect.

8. What has been said above is corroborated by the fact that the industrialisation of the developing countries requires immense investments, and the procuring of the money needed is a fundamental task. Both sources of investments, the domestic and the external ones play an important role in this respect. The mobilisation of both is indispensable for the realisation of effective industrialisa-

tion. The major part of the national income in less developed countries is derived from agriculture or extracting industries where the rate of accumulation is low. To increase accumulation deriving from agriculture is of high importance. One of its preliminary conditions is the realisation of a general land reform. By this means commodity production increases, labour becomes more productive, purchasing power of the agricultural population becomes greater, and finally the source of accumulation expands. The internal resources of accumulation may be increased by the prevention of the outflow of capital, the limitation of the profit withdrawals of foreign capital and several further steps to be taken in order to assure the profits, deriving from the countries' own natural resources and from the nations' own work to the purpose of its own development, and industrialisation. The employment of surplus labour resulting in the increase of purchasing power augments in different ways the domestic sources of accumulation, too.

9. To take the effective measures necessary for industrialisation requires an economic policy elaborated according to the specifical economic conditions of the country. It demands, on the other hand, the existence of certain organisational preconditions of the implementation of such an economic policy. Only the government can take stock of all the economic resources, coordinate and carry out the various measures. Therefore a basic condition for the implementation of a policy of industrialisation is the growth of the economic guiding role of the state. It is difficult to point out in a brief lecture all the domains where the state has a decisive role to play, all the levers by means of which the government can purposefully advance the realisation of industrialisation. Therefore I shall mention only a few of them.

10. The implementation of a policy of industrialisation presupposes that the trend of the flow of capital within the country as well as the whole financial and price system should be favourable to industrialisation. The price problem is very important in the phase of industrialisation, since the demand for commodities grows in consequence of the acceleration of economic development, and that again may lead to an increase in the prices and can easily start inflation. That alone demands that the government should pay particular attention to the questions of price control and, in the case of necessity, of fixing certain prices. The price policy is, however, important also because the state can, by a purposeful price and tax policy, effectually promote the development of such branches of industry which are in the foreground of the established plan of industrialisation. The elaboration and application of a customs policy to the aims of industrialisation are in some respect related to it. Imports may often be regulated in this manner, for instance, by levying low duties or no duties at all on the necessary goods and higher duties on less important goods, for instance, luxury articles. At the same time an increased custom protection should be extended to the existing industries, first and foremost, to those which may count for further development. The custom protection is justified in the case of developing young industries which, of course, could not compete with the well established big industries of many other countries. In many cases the application of export duties or government subsidies for promoting exports may be instrumental in changing the structure of exports, mainly when the products in question leave the country

not only in the form of raw materials, but semi-finished or finished goods, and the government can purposefully promote the exportation of the latter.

11. An equally important factor is the control of the credit system, or more precisely the realisation of a credit policy which serves entirely the aims of industrialisation. Only such a centrally directed credit policy is capable of concentrating the financial means on spheres which should be developed, while limiting, of course, utilization in all other spheres. All this is proved by experiences of countries which have made considerable progress in industrialisation.

12. All this presupposes that the government should draft such an economic plan for industrialisation which takes into account all available resources, covering the whole of economic life. Besides the plan for action which may guide the activity of the government and several government agencies for a relatively short period e.g. a year; plans for longer period are also needed. The latter are of a different, more general character, but certainly such perspective plans ought to be elaborated for the whole process of industrialisation, to make clear the general trend to be followed and the measures to be taken. This requires the government to have a state agency for the elaboration of such economic plans and for the coordination and control of their execution. To carry out the plans needs concerted action of government or better to say, needs all the powers at the disposal of the state. The active role of the state, that of the government in respect of economic policy will certainly increase considerably in the period of industrialisation - as many of the levers necessary to this end are, or can be disposed of only by the government. This stresses the special responsability of the state, and the countries' government for industrialisation.

13. All this is intended to ensure that the countries embarking on the road to industrialisation might exploit and concentrate their own resources to the maximum toward this aim. It is, however, well known that the domestic resources do not suffice - even in this case - to ensure the required tempo of industrialisation. At present the inner accumulation in developing countries amounts to - roughly - $ 11 billion and this would produce an increase of $ 4-5 billion by the afore-said methods. As in developing countries an 18 to 20 % investment quota of the national income would be reasonable - against the average of 12 % in highly developed capitalist countries, the investments can only partly be covered from domestic resources. Foreign credits, loans are necessary, too.

Utilization of foreign resources has so far created a situation in which foreign capital was mainly invested in the extracting industries, thereby preserving the one-sided character of the economy and increasing the economic dependence of the countries concerned. Foreign capital invested mostly in extractive branches of industry or agriculture, generally with high interest rates- and in the case of private capital - with a consequence of great outflow of profits - did not favour industrialisation, and in consequence did not alter the economic backwardness and dependence of the less developed countries. This does not refer to the financial means given by the socialist countries, which never took

the form of direct investments, but loans to the government with low interest rates generally to promote industrialisation and to strengthen the economic independence of the less developed countries. However, a considerable part of the credits from other sources place a great financial burden upon the recipient countries. This is one of the causes of the large and increasing indebtedness of the developing countries. The heavy repayment obligations diminish the possibilities of investment.

15. To promote the trend of industrialisation, it would be a favourable solution to make the foreign credits and loans available directly to the governments of the developing countries. These sources of investments could be utilized, on the basis of the government's economic policy and well considered plans, in spheres which are in the line of the established trend of economic development. As to the credit-terms, the particular circumstances of the recipient country and the domain of utilization of the credits should be taken into consideration. The repayment of credits is easier if the reimbursement of the given investment is taken carefully into consideration. As a matter of course, it is easier to begin repaying the long-term credits when the new industrial establishment built by means of credit has been put in operation. The mode of payment is also connected with this. For a developing country it is most reasonable to pay either with the products of the new plant or - with the usually exported goods. In case of big projects it may be reasonable for several countries to realise such projects in cooperation. This certainly presupposes the existence of international cooperation on a large scale. That is, a revaluation of the credit policies applied thi far is necessary. The right policy which should prevail in the field of credits, and international financial cooperation, should take fully into consideration the real interests of the less developed countries, advance their industrialisation, the differentiation of their economies as well as the consolidation of their economic and political independence.

16. International cooperation ought to be realised in other spheres as well with a view to the effective, quick and manysided development of the less developed countries. In these countries all specialists and skilled workers are not at hand, whose presence is indispensable for industrialisation. Many members of the skilled personnel are foreigners even at present in the existing factories. This problem cannot be solved overnight. The training of national - and it should be stressed - national specialists, engineers, and skilled workers ought to be speeded up. Obviously this too is to be reached only through a world-wide cooperation among nations.

17. Today it must also be considered that the structure of the world's trade is gradually changing in consequence of the development of less developed countries. In the export of developing countries the share of raw materials and foodstuffs will register a relative decrease, while the share of manufactured goods and finished products will increase. Now already the difficulty of the sale of manufactured goods is manifest in less developed countries. Therefore the safeguarding of markets for the products of the developing countries, especially for those of their young

industries, and at the same time the covering of their increasing import, deserve special attention. This complicated question can not be solved without making international surveys and coordinating the trade policies.

18. The industrialisation of economically less developed countries is a task which calls for a world-wide international cooperation. To study the experiences of rapid development, and especially problems of industralization may also be extremely useful on an international level. Industrialisation in Hungary in the last 15 years has been very swift. True, Hungary had industry before the war, too; but the rapid development of the last fifteen years raised many questions of industrialisation which are instructive also for countries where industrialisation is on a much lower level. The evaluation and publication of experiences is an important task of the United Nations. The transfer of experiences is, of course, always possible on a bilateral basis between the interested countries, but the UN could do here useful and manifold work.

19. The progress in the industrialisation of less developed countries is far from being satisfying. It must be realised at last that the solution of the question is pressing and quick action is needed. It must be recognized that international cooperation is badly needed for the realisation of industrialisation with the participation of all countries of the world.

A work of this sort on a suitable level and with suitable cooperation would in a brief time change the aspect of the world. It is feasible that the peoples living still in primitive conditions in the greater part of the world enter the 20th century in the full meaning of the word and enjoy all the advantages of technical and social progress.

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FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

SUMMARY

Agenda Item: D

Hungary

INDUSTRIALIZATION IN ECONOMICALLY LESS DEVELOPED COUNTRIES

By Dr. János SZITA, Director,
Hungarian Planning Office,
Budapest, Hungary

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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INDUSTRIALIZATION IN ECONOMICALLY LESS DEVELOPED COUNTRIES

by
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Summary

1./ Industrial development is the most important factor of economic progress in the less developed countries. The development of industrial production enables the country to reach a higher national income, to liquidate the one-sidedness of the economy, to diversify economic life, and to create new openings, new opportunities to work. Industrialization opens a way towards developing an advanced society.

2./ Development of industry, of course, does not preclude the possibility of developing other branches too of the economy /agriculture, fishing, etc./, though a successful development of the latter often depends on the existence of certain industrial activities, on the development of certain branches of industry.

3./ The absolute necessity of industrialization itself does not determine, what branch or branches of industry should be developed in various countries. That must be decided upon with great care and circumspection. Above all, it must be established what are the factors that affect most the fixing of the objectives for industrial development.

Such factors are in any case:
the natural resources of the country,
the state of development in other fields of the economy /agriculture, other extractive branches, transport, etc./,
the general level of consumption of the population and its pattern,
the volume and pattern of foreign trade,
the labour supply.

Special care should be devoted to investigate the character and pattern of the industries already existing in the country and the development in process. Besides, special consideration should be given to the possibilities offering themselves for processing the countries' own raw materials, or more precisely:

what stage of processing is it advisable to set as a practical objective in this respect.

4./ Industrialization affects the whole economic and social life. The connections between industrial development and the diverse fields of economic and social life must, therefore, also be revealed, e.g.:

Exploitation of sources of energy, supply of energy, transport problems /freight and passenger transport/, Labour supply /from highly qualified personnel to unskilled labour/,

Public health,

Housing,

Trade /in connection with the growing demands of the population/,

Foreign trade /in connection with the increasing industrial activity/

5./ Problems connected with international co-operation:

a./ Ensuring the means, machines, and equipment needed for the development of industry; their installation;

b./ International co-operation in training and securing skilled labour,

c./ Marketing of industrial products,

d./ International financial assistance.

For the last 15 years, the rate of industrialization in Hungary has been very quick indeed. True enough, Hungary had an industry before the war, too. The development since, however, has raised a number of problems connected with industrialization that might be instructive in several respects for such countries where industrialization is on a much lower stage.

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Agenda Item: D.4.2

Sweden

ASEPTICALLY PACKED MILK IN ONE-WAY CONTAINERS WITH A SHELF-LIFE OF 4 WEEKS WITHOUT REFRIGERATION, A REVOLUTIONARY NEW TECHNIQUE WITH IMPACT ON MILK DISTRIBUTION : DAIRY LOCALIZATION AND MILK PRODUCTION POTENTIALS

By Hans RAUSING, B.A.,
Managing Director of AB Tetra Pak,
Lund, Sweden

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ASEPTICALLY PACKED MILK IN ONE-WAY CONTAINERS WITH A SHELF-LIFE OF 4 WEEKS WITHOUT REFRIGERATION - A REVOLUTIONARY NEW TECHNIQUE WITH IMPACT ON MILK DISTRIBUTION, DAIRY LOCALIZATION AND MILK PRODUCTION POTENTIALS

by
Mr. Hans Rausing, B.A., Managing Director of AB Tetra Pak,
Lund, Sweden.

This paper discusses some aspects of a new and entirely different approach to the problems of milk (albumin distribution, especially in warm countries, through UHT-treated milk, aseptically packed in Tetra Pak.

The two greatest problems of milk distribution in less developed areas, especially in hot climates, are time and temperature. Ordinary pasteurized milk has, for instance in India, a life-time of only a few hours. Refrigeration chains from the dairy to the housewife are in most cases impossible to build up because of the high investment costs. The logical result has been that the dairy industry has become localized within a short distance of the consumption centers. Now the consumption centers seldom lie in the areas most suitable for milk production. At the same time the production of fresh vegetables and other perishable goods around the towns competes with milk production.

For many years it has been possible to sterilize milk in glass bottles. This milk has never become extensively used, partly

because of the inferior quality of the milk after the in-bottle sterilization process, partly

because of the inherent, possibly unsolvable hygienic difficulties connected with the use of reusable containers for sterile products in hot climates and lastly,

because the glass bottles as such can only be used for short-distance, local transportations and consequently the sterilized bottle cannot solve the problem how to increase the supply of nationally produced milk to the low income consumers in the less developed areas.

For many years it has been obvious that the only logical solution of this problem would be a nonreturnable milk container with a shelf-life - under unrefrigerated conditions - of at least a few weeks. It has also been clear that no large volume operation could be built up unless the milk was put on the market at a cost which would be reasonable also for the ordinary workman. Milk should not be a luxury product. This consideration has until now ruled out all possible packages, since until now no package has existed which

1. gave the milk a shelf-life of 4 weeks without refrigeration,
2. was nonreturnable,
3. could be produced in any size from less than one oz. up to 1 quart,
4. was sufficiently economical also in small sizes so that the average workman can find a size the price of which lies within his means,
5. made possible sterilizing methods which give a good quality milk,
6. avoided the destruction of up to 30 % of the milk's albumins through the in-the-bottle sterilization.

The chemical changes through in-bottle sterilization have the

effect that up to 30 % of the milk albumins cannot be digested or used by the human body. This hidden and relatively unknown fact means for glass bottles a hidden cost increase, since the destroyed milk is wasted and useless, even if it is consumed.

This destruction of the milk can be avoided by cutting down the time the milk is exposed to heat from 15 - 20 minutes to a few seconds.

For many years it has been possible to make milk entirely free from bacteria through a shock treatment with heat. The milk is heated for a period of 2 - 5 seconds with temperatures ranging up to 145°C in special machines. These machines have been used in practice only to a small extent, since the high quality milk they give - a quality comparable with ordinary pasteurized milk with regard to taste, nourishment etc. - has not been possible to distribute. In the packaging process the milk has been reinfected and consequently the machines have offered no advantage over ordinary pasteurizing machines.

All this is changed by Tetra Pak Aseptic. Tetra Pak Aseptic is a modified version of the well-known Tetra Pak machines. All Tetra Pak machines form the packages from a roll of paper which is formed continuously into a tube and then in one operation filled and heatsealed into tetrahedrons.

(Picture)

The Tetra Pak Aseptic machines let the paper go through a peroxide bath so that the inside of the paper tube is moist. In the tube about 4 feet above the milk level an electrical element is placed which causes the peroxide on the paper surface to boil. This boiling peroxide gives full sterility. At the same time the heat

splits the peroxide into oxygen and water which is reduced to vapour. The lowest part of the heating element creates a "dry zone" which gives the dairy a safety margin and an absolute guarantee that no peroxide can ever come in contact with the milk.

The aseptic "chamber" consequently consists of the lower part of the paper tube itself. There are no moving parts on the inside of the tube. Since the heatsealing jaw and all other machine parts work only against the outside of the tube it is not necessary to sterilize them.

It is consequently possible to fill the ultra-high-temperature-heated milk - with its excellent quality - into Tetra Pak containers under aseptic or sterile conditions. The milk will keep for one month without refrigeration.

This extremely simple method of packing milk aseptically, which was technically possible only because of the continuous Tetra Pak system, has now been thoroughly tested in commercial operation.

In the highly industrialized countries with their quickly increasing wage costs and ever more difficult transportation (distribution) problems (traffic snarls, parking problems etc.) the savings in the distribution costs may be decisive. Aseptically packed milk can also be bought and stored by the housewife in the same way as other products so that she always can have a supply of milk at home and does not have to shop every day.

In countries with a low standard of living the costs of operating glass bottle plants are often quite high and the hygienical problems connected with returnable containers in a hot climate may be difficult

to solve. This is one of the reasons why for ordinary pasteurized milk the use of nonreturnable (Tetra Pak) containers is spreading rapidly also in these countries.

Aseptic filling makes possible an entirely new approach to the problem of milk distribution in the hot countries. The investment costs are far lower than those of any other method, since no refrigeration of the milk is necessary either in the dairy after filling or in the distribution system. Milk aseptically packed in Tetra can be stored for as much as a month. It is therefore possible to situate dairies where milk is available, not necessarily where the consumers live. In many areas the potential milk supply cannot be utilized in its fluid form in a rational way for lack of markets. The milk is in one district, and the customers for fluid milk may live hundreds of miles away.

Sometimes, for lack of markets, the milk is not produced at all or on a far lower scale than the potential one.

With Tetra Pak Aseptic the national production of milk can be increased in a faster and more rational way.

An additional advantage is that, generally speaking, areas situated near consumption centers and now used for the production of milk should be made available for production of fresh vegetables etc.

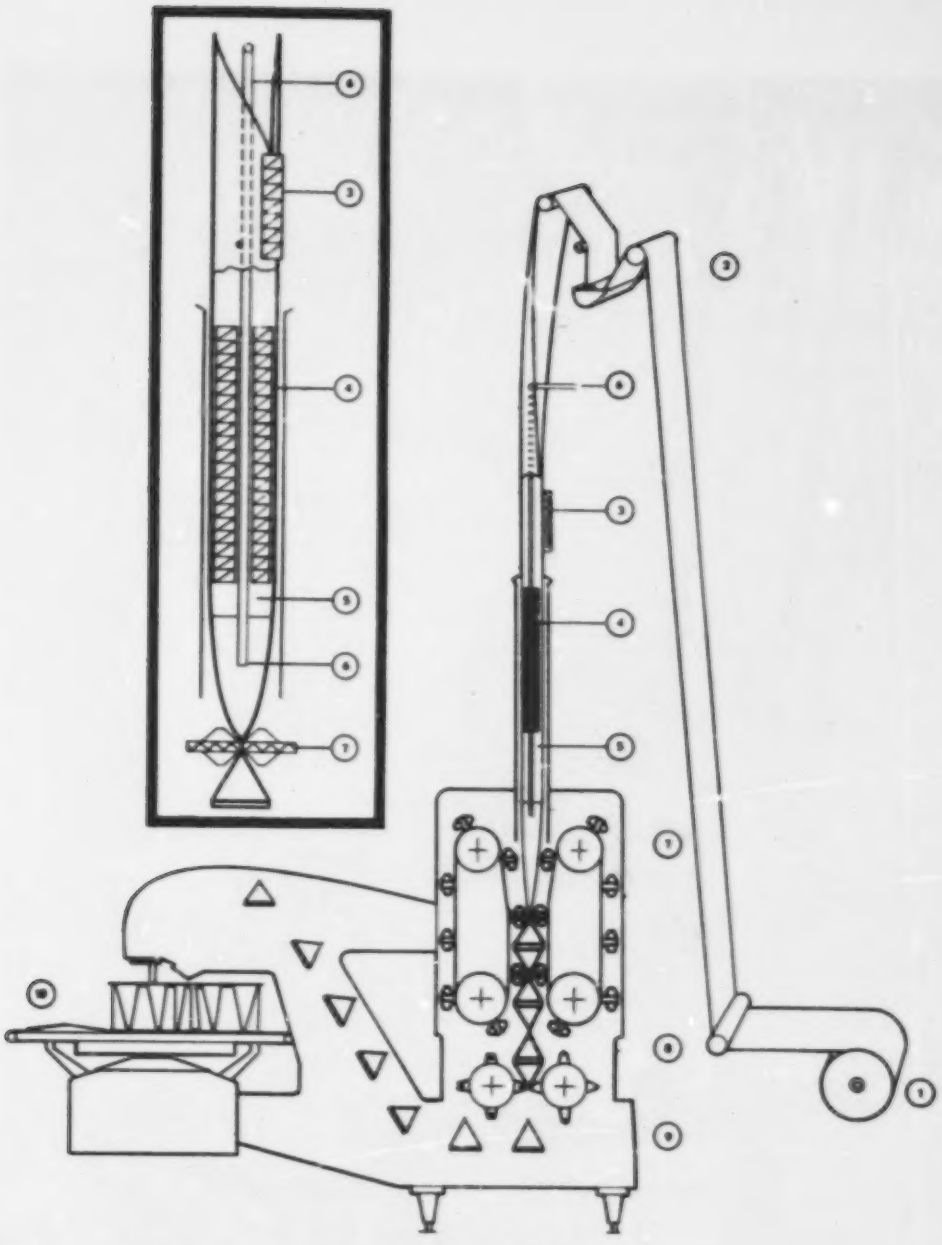
It is difficult to estimate the costs of the Tetra Pak Aseptic system. In many cases the total cost for aseptic Tetra Pak milk (counting also supply and distribution costs) will be lower than for instance the costs of pasteurized milk. More important is perhaps that Tetra Pak Aseptic often may be the only economically possible way to arrange for a supply of milk to a certain area or to provide outlets for the milk from an isolated production district. In each country a calculation must be made taking in

regard the local conditions (transport distances, type of distribution system, supply sources of raw milk etc.).

It is a well-known fact that the costs of packing a given quantity of milk in Tetra packages are about half of the corresponding costs for other one-way cartons. It is of great importance that costs within the dairy of the Tetra Pak aseptic method - while higher than the cost for ordinary Tetra packages - are still lower than the corresponding costs of any other milk carton - and you get the one month shelf-life into the bargain.

In other words, Tetra Pak Aseptic gives you a lower cost than other cartons for pasteurized milk and in addition the tremendous advantage of having a milk which keeps without refrigerating for one month, which can be transported for thousands of miles and which can be sold through the same type of retail outlets as ordinary consumption goods.

A final aspect of the Tetra Pak method is that the relative economy in relation to all other methods, cartons or bottles, is improved as the size of the package gets smaller. This has very practical significance in countries with a low standard of living where it is important to supply relatively small quantities of milk so as to enable also the poor man to buy at least a minimum of this vital food.



The Tetra Pak machine incorporated in the plant is a standard model modified as shown in the diagram above.

1. Roll of paper.
2. Chemical bath
3. Longitudinal heat sealer
4. Element for heating the tube
5. Bacteria free region
6. Milk input pipe
7. Heat sealing jaws for the transverse seam
8. Cutter
9. Conveyor belt
10. Automatic crater

Fig. 1 - The principle of Tetra Pak Aseptic.

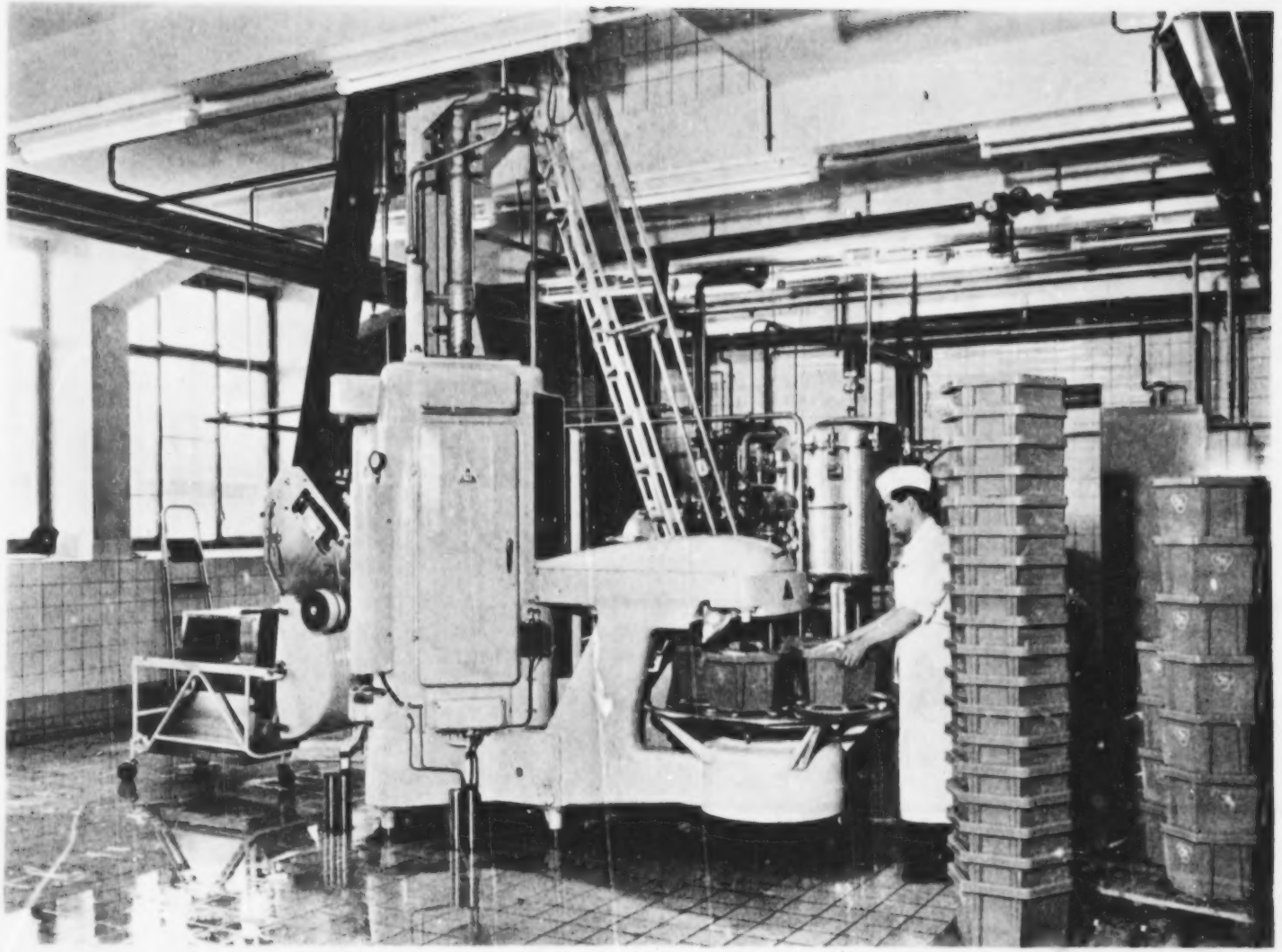


Fig. 2 - The first Tetra Pak Machine for aseptic filling - in series production - at work at Verbandsmolkerei Bern. Eighteen months of continuous marketing research with an experimental machine preceded the introduction of this machine on a commercial basis. Throughout this period, milk treated by steam injection and packed aseptically in Tetra Pak at the Bern dairy was distributed without the consumers noticing any difference between this milk and the usual pasteurized product.

Fig. 3 - Milk with a shelf-life of one month means that milk can be sold over the counter just like any other product - without refrigeration and without special storage facilities. Sales methods, and the supply on which these methods are based can be put on a completely new footing, and milk can be made available to the consumer in quite a different way from previously.

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by

Mr. Hans Rausing, B.A., Managing Director of AB Tetra Pak, Lund, Sweden

SUMMARY

Aseptic filling of UHT-treated milk in Tetra Pak Aseptic gives you

1. A milk in a one-way Tetra Pak carton with a shelf-life of one month,

2. A milk with the quality of pasteurized milk - the destruction of up to 30 % of the milk albumins through in-the-bottle sterilization is avoided,

3. A possibility to localize your dairies in the milk production areas rather than in the consumption areas - and thus a possibility to increase the national production and consumption of milk,

4. A system where the packaging economy is relatively independent of the size of the packages - which makes it possible to sell units small enough to lie within the economical means of the ordinary workmen,

5. A one-way package with one month's shelf-life and superior economy, which makes a wholly new approach to the distribution channels possible.

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